

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

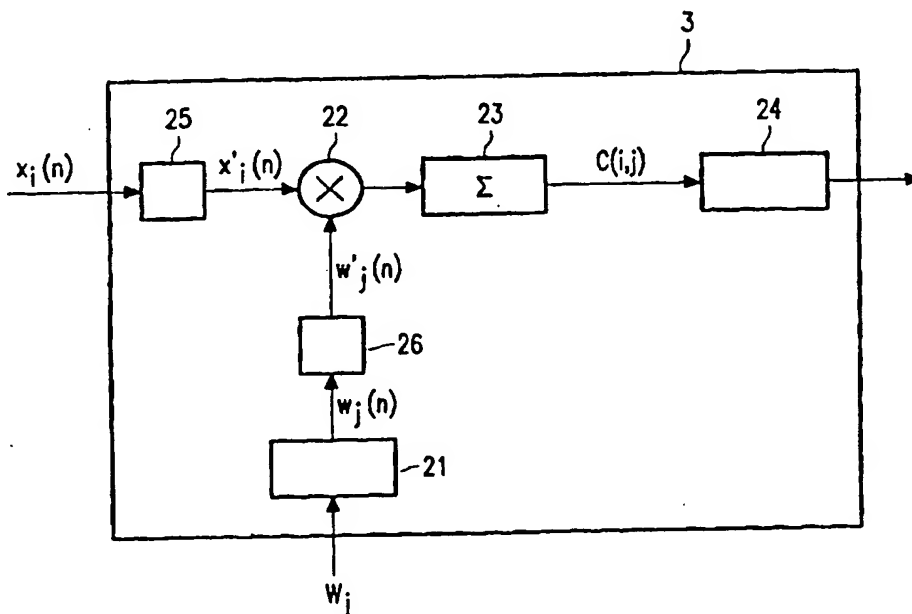


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H04N 7/08, H04L 9/32	A1	(11) International Publication Number: WO 98/03014 (43) International Publication Date: 22 January 1998 (22.01.98)
(21) International Application Number: PCT/IB97/00692 (22) International Filing Date: 12 June 1997 (12.06.97) (30) Priority Data: 96202016.0 16 July 1996 (16.07.96) EP (34) Countries for which the regional or international application was filed: AT et al. (71) Applicant: PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). (71) Applicant (for SE only): PHILIPS NORDEN AB [SE/SE]; Kottbygatan 7, Kista, S-164 85 Stockholm (SE). (72) Inventor: LINNARTZ, Johan, Paul, Marie, Gerard; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). (74) Agent: SCHMITZ, Herman, J., R.; Internationaal Octrooibureau B.V., P.O. Box 220, NL-5600 AE Eindhoven (NL).		(81) Designated States: JP, KR, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

BEST AVAILABLE COPY

(54) Title: **DETECTING A WATERMARK EMBEDDED IN AN INFORMATION SIGNAL**



(57) Abstract

A watermark embedded in an information signal is detected by correlating said information signal with a plurality of watermarks $W_j(n)$. The respective amounts of correlation $C(i,j)$ are then evaluated to determine the watermark embedded in the signal $x_i(n)$. The invention provides a significant improvement of the detection by predictive filtering (25) the information signal and/or predictive filtering (26) the applied watermark prior to the process of correlating the signals.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

Detecting a watermark embedded in an information signal.

The invention relates to a method of detecting a watermark embedded in an information signal, comprising a correlation step for correlating said signal and an applied watermark, and an evaluation step for evaluating the result of said correlation. The invention also relates to a method for carrying out said method.

5

Watermarks are perceptually invisible messages embedded in multimedia content such as audio, still images, animations or video. They comprise information, for example, about the source or copy right status of documents or audiovisual programs. Watermarks can be used to provide legal proof of the owner of the copyright. They allow tracing of piracy and support the protection of intellectual property.

10

A known method of detecting a watermark embedded in an information signal comprises a correlation step for correlating said signal and an applied watermark. The result of said correlation is then evaluated. For example, if the amount of correlation is larger than a predetermined value, the applied watermark may be considered to be the watermark embedded in the signal. Alternatively, a number of successive correlation steps can be carried out for different applied watermarks. The applied watermark yielding the largest correlation is then considered to be the watermark embedded in the signal.

15

OBJECT AND SUMMARY OF THE INVENTION

20

It is an object of the invention, inter alia, to provide a method with which an embedded watermark can yet more reliably be detected.

To that end, the method is characterized by the steps of predictive filtering the information signal or the applied watermark or both, and applying the correlation step to said filtered signal and said filtered watermark.

25

The invention is based on the recognition that the problem of detecting watermarks closely resembles the detection of weak radio or radar signals in the presence of strong interference or noise. By predictive filtering, i.e. subtracting a prediction of the information signal from said signal, a residual signal is obtained having a significant lower

variance. This means that the interference which the watermark suffers from the residual information is considerably less than it suffers from the original signal.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

Fig.1 shows schematically an arrangement for watermarking a video signal.

Fig.2 shows schematically a prior art arrangement for detecting a watermark embedded in the signal which is generated by the arrangement shown in Fig.1.

Figs. 3 and 4 show schematically arrangements for detecting the watermark in accordance with the invention.

The invention will herein be described by way of an example of detecting a watermark which is embedded in a digital video signal. The watermarks can be added in almost every domain such as, for example, the time domain, the spatial domain, the transform domain after DCT or Fourier transform, etc. In the present example, it is embedded in the spatial domain, i.e. it is added to the luminance pixel values of a digital video signal.

Fig.1 shows schematically an arrangement 1 for watermarking the video signal. The arrangement receives a video signal in the form of luminance samples or pixels $p(n)$ and a watermark W_i . The watermark can be a code which uniquely identifies the owner of the copyright. It can also be a text string or simply a binary coded number. Accordingly, there is a finite set of different watermarks W_i . The arrangement comprises a watermark data signal generator 11 which generates a predetermined watermark data signal $w_i(n)$ for each watermark W_i . The luminance value $p(n)$ and watermark data value $w_i(n)$ are added by an adder 12 pixel-by-pixel. Accordingly, the output signal $x_i(n)$ of the watermarking circuit 1 is:

$$x_i(n) = p(n) + w_i(n)$$

The watermark data signal $w_i(n)$ is chosen such that it is perceptually invisible when the output signal is displayed on a receiver. For example, a small value is added to the luminance of selected pixels $p(n)$ of the video image, the watermark W_i determining the selected pixels. An example hereof will now be given in terms of an image of 8 pixels horizontally and 4 pixels vertically. It is to be noted that the method can also be applied to a predetermined part of the image. The method can also be applied to a plurality of image blocks, each block being associated with a portion of the watermark.

In the present example, the value 1 is added to the luminance of selected pixels whereas other pixels remain unaffected. The following equation denotes a watermark data signal $w_1(n)$ that is generated by watermark data signal generator 11 in response to a first watermark W_1 :

$$w_1(n) = \begin{matrix} & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 5 & & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ & & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \end{matrix}$$

The following equation denotes a watermark data signal $w_2(n)$ that is generated by the watermark data signal generator if a second watermark W_2 is applied:

$$w_2(n) = \begin{matrix} & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ & & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \end{matrix}$$

In this manner, the watermark data signal generator 11 generates a different watermark data signal $w_i(n)$ for each watermark W_i .

In the present example, the video image is assumed to represent a vertical transition from a luminance value 10 to a luminance value 80. The range of luminance values $p(n)$ is assumed to be 0-255. In mathematical notation:

$$p(n) = \begin{matrix} & 10 & 10 & 10 & 10 & 80 & 80 & 80 & 80 \\ & 10 & 10 & 10 & 10 & 80 & 80 & 80 & 80 \\ & 10 & 10 & 10 & 10 & 80 & 80 & 80 & 80 \\ & & 10 & 10 & 10 & 10 & 80 & 80 & 80 & 80 \end{matrix}$$

15 Accordingly, if watermark W_1 is applied to arrangement 1, the watermark data signal $w_1(n)$ is added to image signal $p(n)$, which results in the following output signal $x_1(n)$:

$$x_1(n) = \begin{matrix} & 10 & 11 & 10 & 11 & 80 & 81 & 80 & 81 \\ & 11 & 10 & 11 & 10 & 81 & 80 & 81 & 80 \\ & 10 & 11 & 10 & 11 & 80 & 81 & 80 & 81 \\ & & 11 & 10 & 11 & 10 & 81 & 80 & 81 & 80 \end{matrix}$$

Similarly, if watermark W_2 is applied to the watermarking arrangement, the watermark data signal $w_2(n)$ is added to image signal $p(n)$, which results in the following output signal $x_2(n)$:

$$x_2(n) = \begin{matrix} 10 & 10 & 11 & 11 & 80 & 80 & 81 & 81 \\ 11 & 11 & 10 & 10 & 81 & 81 & 80 & 80 \\ 10 & 10 & 11 & 11 & 80 & 80 & 81 & 81 \\ 11 & 11 & 10 & 10 & 81 & 81 & 80 & 80 \end{matrix}$$

It will be appreciated that neither the difference between an output signal $x_i(n)$ and input signal $p(n)$, nor the difference between output signals $x_1(n)$ and $x_2(n)$, is perceivable for a human visual system. The output signal $x_i(n)$ is stored on a storage medium such as an optical disc or a magnetic tape, or transmitted through a transmission channel (not shown in Fig. 1).

Fig. 2 shows schematically a prior art arrangement 2 for detecting the watermark W_i embedded in the signal $x_i(n)$. The arrangement receives a watermark W_j and delivers an indication of whether or not the applied watermark W_j resembles the embedded watermark W_i , i.e. whether $i=j$ or not. The arrangement comprises a watermark data signal generator 21 which is identical to, and produces the same watermark data signal $w_j(n)$ as the watermark data signal generator 11 which is shown in Fig. 1. The input signal $x_i(n)$ and the watermark data signal $w_j(n)$ are applied to a circuit which is often referred to as a matched filter or correlator. In the embodiment shown in Fig. 2, said correlator comprises a multiplier 22 and a summation circuit 23. The correlator performs the following mathematical operation:

$$C(i, j) = \sum_{n=1}^N x_i(n) * w_j(n)$$

in which N denotes the total number of pixels. It will be appreciated that, if the information signal is an analog signal, for example a time continuous signal $x(t)$, the summation circuit 23 will be an integrator.

The correlator output is a number $C(i, j)$ which represents an amount of correlation between the input signal $x_i(n)$ and the watermark data signal $w_j(n)$. In an evaluation circuit 24, the value $C(i, j)$ is evaluated for various watermarks W_j . The watermark W_j yielding the highest correlation is then assumed to be the watermark W_i . Only two different watermarks are considered here.

- The correlation $C(i,j)$ can easily be calculated. If watermark W_1 is embedded in the signal, the correlation between $x_1(n)$ and $w_1(n)$ appears to be $C(1,1)=736$ whereas the correlation between $x_1(n)$ and $w_2(n)$ appears to be $C(1,2)=728$. Because $C(1,1)$ is greater than $C(1,2)$, the evaluation circuit 24 determines that the embedded watermark is W_1 . If watermark W_2 is embedded, the correlation between $x_2(n)$ and $w_1(n)$ appears to be $C(2,1)=728$ whereas the correlation between $x_2(n)$ and $w_2(n)$ appears to be $C(2,2)=736$. Because $C(2,2)$ is greater than $C(2,1)$, the evaluation circuit 24 determines that the embedded watermark is W_2 . The following Table I summarizes the above results. The rows of this Table denote input signal $x_i(n)$, i.e. the input signal in which a watermark W_i is embedded.
- 10 The columns denote watermark W_j which is applied to arrangement 2.

	W_1	W_2
$x_1(n)$	$C(1,1)=736$	$C(1,2)=728$
$x_2(n)$	$C(2,1)=728$	$C(2,2)=736$

Table I

- 15 It will be appreciated from this example that the values of $C(i,j)$ representing the amounts of correlation are close to each other. This means that the detection circuit is vulnerable with respect to noise, transmission errors, coding errors, etc.

- Fig.3 shows schematically an arrangement 3 for detecting the watermark W_i embedded in the signal $x_i(n)$ in accordance with the invention. The arrangement comprises the same watermark data signal generator 21, multiplier 22, summation circuit 23 and evaluation circuit 24 as are shown in Fig.2. The arrangement further comprises a first predictive filter 25 and a second predictive filter 26. The first predictive filter 25 is connected between the signal input and the multiplier 22. It filters the input signal $x_i(n)$ and generates a filtered input signal $x_i'(n)$. The pre filtering process is also called "whitening", similar to filters that decorrelate noise in radar and radio communication receivers.
- 20
- 25

- The second predictive filter 26 is connected between the watermark data signal generator 21 and the multiplier 22. It filters the locally applied watermark data signal $w_j(n)$ and generates a filtered watermark data signal $w_j'(n)$. The structure of each predictive filter is based on statistical properties of the information signal. Such filters are known per se in the field of source coding. Examples are linear predictive filters as used in DPCM image and speech coding. Other examples are combinations of a transform, a prediction for each frequency subband or transform coefficient, and an inverse transform.
- 30

In the present example, in which the input signal is a digital video image, predictive filter 25 predicts each pixel from its neighbours to the left, to the right, above and below. The predicted value is then subtracted from the actual pixel value to obtain a residual value. In mathematical notation:

$$5 \quad y'(u, v) = y(u, v) - \frac{y(u-1, v) + y(u+1, v) + y(u, v-1) + y(u, v+1)}{4}$$

in which u and v denote discrete pixel positions along the horizontal (u) and vertical (v) axes, $y(u, v)$ denotes filter input samples and $y'(u, v)$ denotes filter output samples. Accordingly, the following equations apply to the filtered input signal $x_1'(n)$ and the filtered input signal $x_2'(n)$, respectively (a scaling factor 4 has been applied to maintain integer values):

$$10 \quad x_1'(n) = \begin{matrix} 18 & 14 & 7 & -56 & 147 & 84 & 77 & 164 \\ 14 & -4 & 4 & -74 & 74 & -4 & 4 & 77 \\ 7 & 4 & -4 & -66 & 66 & 4 & -4 & 84 \\ 24 & 7 & 14 & -63 & 154 & 77 & 84 & 158 \end{matrix}$$

$$x_2'(n) = \begin{matrix} 19 & 8 & 13 & -57 & 148 & 78 & 83 & 163 \\ 13 & 3 & -3 & -73 & 73 & 3 & -3 & 78 \\ 8 & -3 & 3 & -67 & 67 & -3 & 3 & 83 \\ 23 & 13 & 8 & -62 & 153 & 83 & 78 & 159 \end{matrix}$$

Further, the first predictive filter 25 and the second predictive filter 26 are the same in this example. Although this is a preferred embodiment which yields the best performance, it is not essential. The filters may be different, or one of the predictive filters 25 and 26 may even be dispensed with. The performance of the watermark detecting arrangement is then still significantly better than the performance of the prior art arrangement. Accordingly, the following equations apply to the filtered watermark data signal $w_1'(n)$ and the filtered watermark data signal $w_2'(n)$, respectively:

$$w_1'(n) = \begin{matrix} -2 & 4 & -3 & 4 & -3 & 4 & -3 & 4 \\ 4 & -4 & 4 & -4 & 4 & -4 & 4 & -3 \\ -3 & 4 & -4 & 4 & -4 & 4 & -4 & 4 \\ 4 & -3 & 4 & -3 & 4 & -3 & 4 & -2 \end{matrix}$$

$$w_2'(n) = \begin{matrix} -1 & -2 & 3 & 3 & -2 & -2 & 3 & 3 \\ 3 & 3 & -3 & -3 & 3 & 3 & -3 & -2 \\ -2 & -3 & 3 & 3 & -3 & -3 & 3 & 3 \\ 3 & 3 & -2 & -2 & 3 & 3 & -2 & -1 \end{matrix}$$

The following Table II shows the amounts of correlation $C(i,j)$ between filtered input signal $x_i'(n)$ and filtered watermark data signal $w_j'(n)$ corresponding with watermark W_j . It will be appreciated from comparison with Table I that the performance of the watermark detector shown in Fig.3 is significantly better than the one shown in Fig.2.

	W_1	W_2
$x_1'(n)$	$C(1,1)=1152$	$C(1,2)=704$
$x_2'(n)$	$C(2,1)=704$	$C(2,2)=952$

Table II

Table III shows the amounts of correlation between filtered input signal $x_i'(n)$ and the unfiltered watermark data signal $w_j(n)$, i.e. if the input signal $x_i(n)$ is subjected to predictive filtering only. The watermark data signal $w_j(n)$ is directly applied to the multiplier 22 in this case. As can be seen, the performance is worse than in Table II but still better than in Table I.

	W_1	W_2
$x_1'(n)$	$C(1,1)=604$	$C(1,2)=544$
$x_2'(n)$	$C(2,1)=544$	$C(2,2)=588$

Table III

Table IV shows the amounts of correlation between the unfiltered input signal $x_i(n)$ and the filtered watermark data signal $w_j'(n)$, i.e. if the watermark data signal $w_j(n)$ is subjected to predictive filtering only. The input signal $x_i(n)$ is directly applied to the multiplier 22 in this case. Again, the performance is worse than in Table II but still better than in Table I.

	W_1	W_2
$x_1(n)$	$C(1,1)=604$	$C(1,2)=544$
$x_2(n)$	$C(2,1)=544$	$C(2,2)=588$

Table IV

5 Fig.4 shows a further embodiment of an arrangement 4 for detecting the embedded watermark. In this arrangement, each pixel of the input signal $x_i(n)$ is multiplied in a multiplier 42 by a specific weighting factor. The products are summed up in a summation circuit 43 which delivers the correlation value $C(i,j)$. A calculating circuit 44 receives the applied watermark W_j and generates the weighting factors using a model of the statistical
 10 properties of the information signal. In this embodiment, predictive filtering is not applied to the input signal but embedded in the calculation circuit 44.

 In summary, a watermark embedded in an information signal is detected by correlating said information signal with a plurality of watermarks $W_j(n)$. The respective amounts of correlation $C(i,j)$ are then evaluated to determine the watermark embedded in the
 15 signal $x_i(n)$. The invention provides a significant improvement of the detection by predictive filtering (25) the information signal and/or predictive filtering (26) the applied watermark prior to the process of correlating the signals.

Claims

1. A method of detecting a watermark embedded in an information signal, comprising a correlation step for correlating said signal and an applied watermark, and an evaluation step for evaluating the result of said correlation, characterized by the steps of predictive filtering the information signal or the applied watermark or both, and applying the correlation step to said filtered signal and said filtered watermark.
2. The method as claimed in claim 1, wherein the predictive filtering is adapted to predetermined statistical properties of the information signal.
3. The method as claimed in claim 1, wherein both predictive filter steps are the same.
4. A method of detecting a watermark embedded in an information signal, comprising the step of filtering said signal using filter coefficients determined by an applied watermark, and evaluating the result of said filtering, characterized in that the filter coefficients are further determined by a model of the statistical properties of the information signal.
5. An arrangement for detecting a watermark (W_i) embedded in an information signal, comprising correlation means (22,23) for correlating said signal (x_i) and an applied watermark (W_i), and evaluation means (24) for evaluating the result of said correlation, characterized by a predictive filter (25) for filtering the information signal or a predictive filter (26) to filter the applied watermark, or both predictive filters, and applying filtered signal and the filtered watermark to the correlation means.
6. The arrangement as claimed in claim 4, wherein the predictive filters (25,26) are adapted to predetermined statistical properties of the information signal.
7. The arrangement as claimed in claim 5, wherein both predictive filters (25,26) are the same.
8. An arrangement for detecting a watermark (W_i) embedded in an information signal (i), comprising a filter (41,42,43) for filtering said signal using filter coefficients, calculation means (44) for calculating said filter coefficients in dependence on an applied watermark (W_i), and means (24) for evaluating the result of said filtering.

characterized in that the calculation means (44) are adapted to further determine the filter coefficients in accordance with a model of the statistical properties of the information signal.

1/2

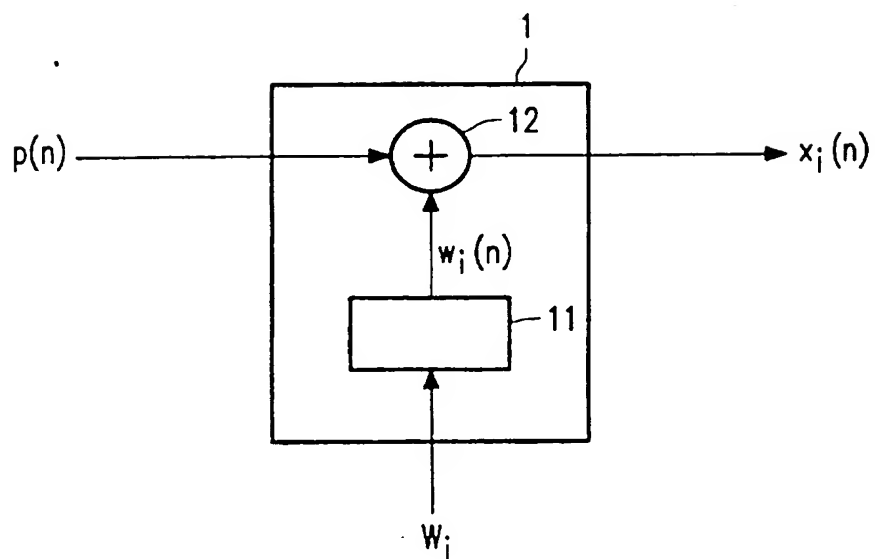


FIG. 1

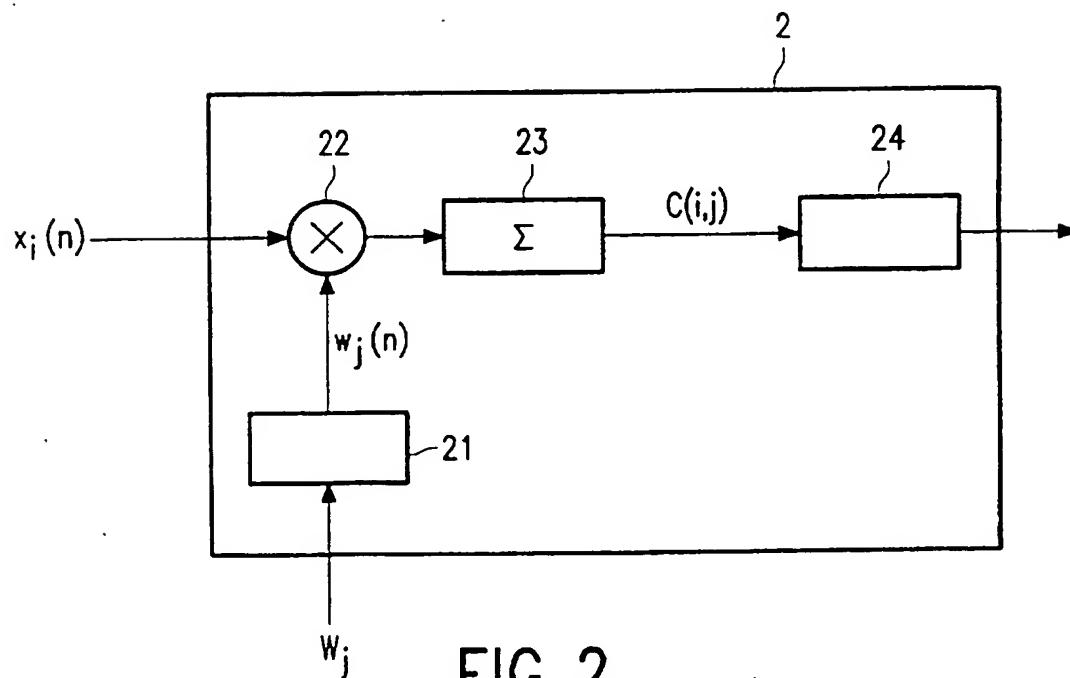
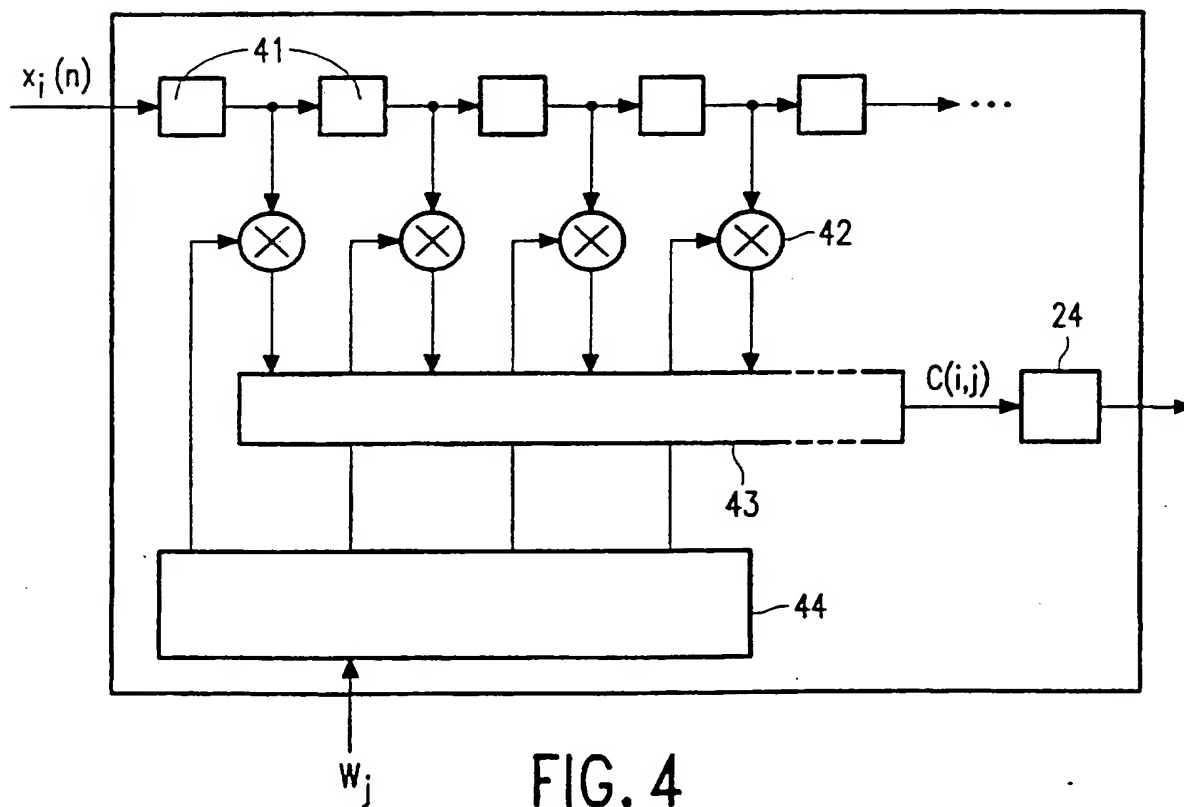
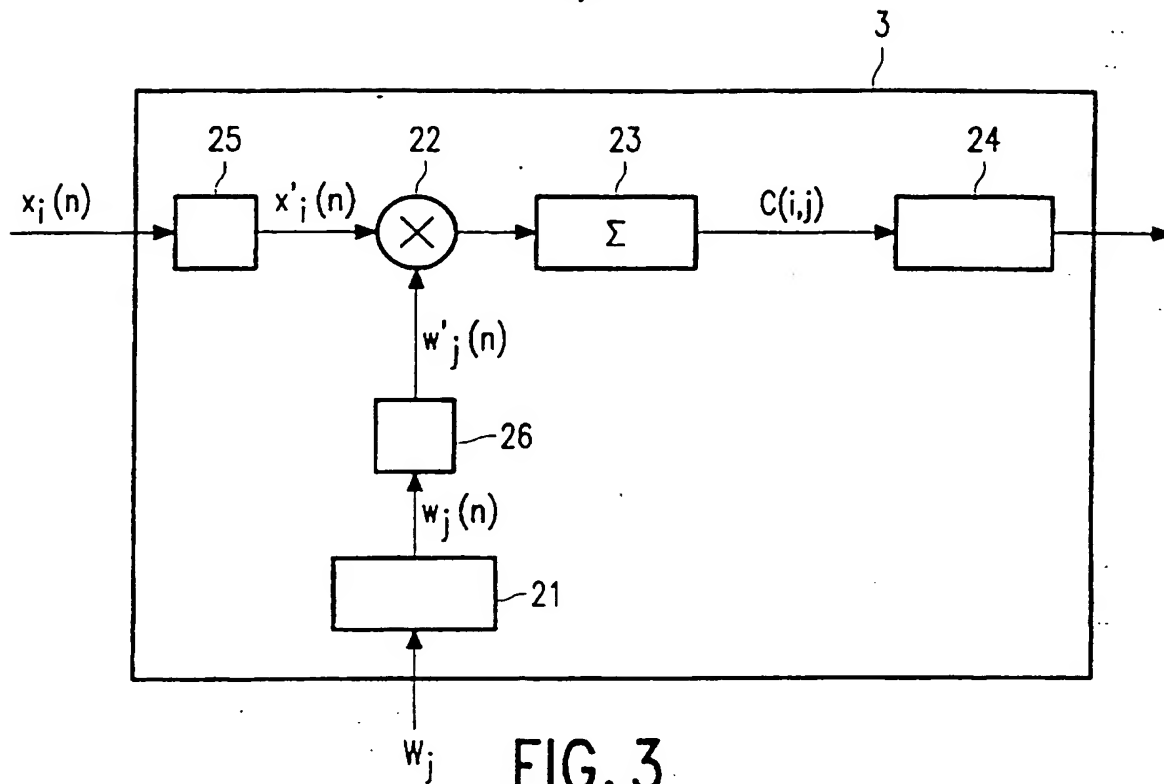


FIG. 2

2/2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB 97/00692

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04N 7/08, H04L 9/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04N, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0766468 A2 (NEC CORPORATION), 2 April 1997 (02.04.97), abstract --	1-8
A	US 5606609 A (HOUSER ET AL), 25 February 1997 (25.02.97), see whole document -- -----	1-8

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

21 November 1997

Date of mailing of the international search report

25 - 11 - 1997

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Rune Bengtsson
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/10/97

International application No.

PCT/IB 97/00692

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
EP	0766468	A2	02/04/97	AU	6584096 A	10/04/97
				CA	2184949 A	29/03/97

US	5606609	A	25/02/97	NONE		

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.